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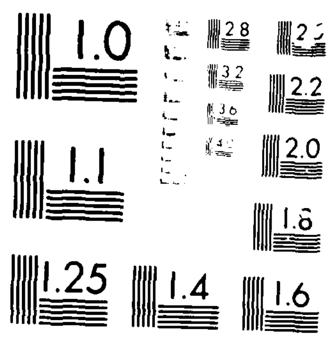
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MEMORANDUM REPORT ARCCB-MR-86013

# A THIN CYLINDER PROBLEM

G. P. O'HARA

APRIL 1986

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT CENTER
CLOSE COMBAT ARMAMENTS CENTER
BENÉT WEAPONS LABORATORY
WATERVLIET, N.Y. 12189-4050

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Stress
Deformation
Cylinder
Thin
Hole

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The purchase of a computer aided design (CAD) system for Benet Weapons Laboratory required the use of a set of demonstration problems which potential contractors would be asked to perform on the different systems. One of these was to be a finite element stress analysis problem which would not be difficult or time-consuming. However, it did have to demonstrate a mesh generation in three dimensions. The problem selected was a thin-walled cylinder with a

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20. ABSTRACT (CONT'D)

single hole at mid-length and loaded with a simple axial tension. This report is an outline of the work done to define this problem and demonstrate a typical solution to it.

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## INTRODUCTION

A test problem was required for the evaluation of the computer aided design (CAD) system, which is currently being purchased by Benet Weapons Laboratory. We needed a relatively simple stress analysis problem which could easily be done on a CAD system, by the potential contractor, to demonstrate a particular system. The geometry selected was a simple thin cylinder of mean radius 1.0 subjected to an axial tension load. The load is distributed at the ends of the cylinder to produce a uniform unit (1.0) nominal stress. The cylinder is 3 PI (9.4278) long and contains a single perforation at mid-length, in the form of a circular hole of radius 0.15. The problem is to find the stress concentration factor (S.C.F.) for the hole when the thickness of the cylinder is 0.0143525. The most desirable solution is for a shell formulation with membrane and bending stiffness terms.

Along with the S.C.F., it is also desirable to generate the following graphic output:

1. A deformed structure plot.
2. A maximum principal stress contour plot on the inside surface.
3. A maximum principal stress contour plot on the outside surface.

If necessary, the problem may be reduced to a membrane problem with only one contour plot.

## REFERENCE SOLUTIONS

There are two readily available solutions to the problem in standard reference books (refs 1,2).

The solution in reference 1 is a shell solution in which the S.C.F. is plotted as a function of a shell stiffness parameter beta. In contrast, the solution in reference 2 is for a thick cylinder in which the S.C.F. is given as an equation using the internal and external diameters along with the radius of the hole. The rather strange thickness of 0.0145325 comes from the desire to read the curves given in Reference 1 at beta = 0.80, which results in an S.C.F. of 4.60. If it is necessary to use a membrane solution without bending terms, the S.C.F. is reduced to 4.00.

## FINITE ELEMENT SOLUTION

The full shell solution has been done on Abaqus at three different thicknesses (Figures 1, 2, 5, and 8). This provided a reference solution to aid the evalution committee. The S.C.F. results are shown in Table I below, and Figures 3, 4, 6, 7, 9, and 10 in this report.

TABLE I. STRESS CONCENTRATION FACTORS FROM SEVERAL SOURCES

| | Thickness | S.C.F. Reference 1 | S.C.F. Reference 2 | S.C.F. Abaqus | Percent Error |
|---|---|---|---|---|---|
| A | 0.00143525 | 8.50 | 3.183* | 7.20 | -15.3 |
| B | 0.0943525 | 4.60 | 3.187* | 4.31 | - 6.3 |
| C | 0.143525 | 3.25* | 3.227 | 3.06 | - 5.2 |

*These solutions are outside of the published limits in the reference.

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[1] R. E. Peterson, Stress Concentration Factors, John Wiley and Sons, New York, 1974, p. 153.

[2] R. J. Roark and C. W. Young, Formulas for Stress and Strain, McGraw-Hill, Fifth Edition, 1965, p. 601.

## DISCUSSION OF THE PROBLEM

There are two small problems that must be pointed out as they could have an impact on the evaluation of other solutions. First, the grid used for this analysis did not concentrate enough degrees of freedom near the hole. This results in a very poor deformed shape for solution 'A' with its rather large error. In other words, the 'near field' region of the hole was larger than was assumed, and element size was increased too fast. In solutions 'B' and 'C', the stiffer shell has reduced the magnitude of this effect. The second problem encountered was that Abaqus did not calculate the surface normal direction accurately for all nodal points and this data had to be input independently. This was a rather large error and until it was corrected, solution 'B' was giving an S.C.F. of 20.2. Both of these effects could be corrected by the rather simple solution of using a large number of elements. This method becomes very easy on a computer graphics system. While a general increase in element density works well on small problems, it is not always possible because of the increase in solution time.

The plots are taken directly from the Abaqus graphics package and are plots of the undeformed grid, the deformed grid, or maximum principal stress contours. The grid is located at the mean radius of the cyinder, but the stress contours are on either side of the cylinder wall. Contour plots for section point one are on the inside of the cylinder and for section point three, they are on the outside.

## REFERENCES


1. R. E. Peterson, Stress Concentration Factors, John Wiley and Sons, New York, 1974, p. 153.
2. R. J. Roark and C. W. Young, Formulas for Stress and Strain, McGraw-Hill Book Company, Fifth Edition, 1965, p. 601.

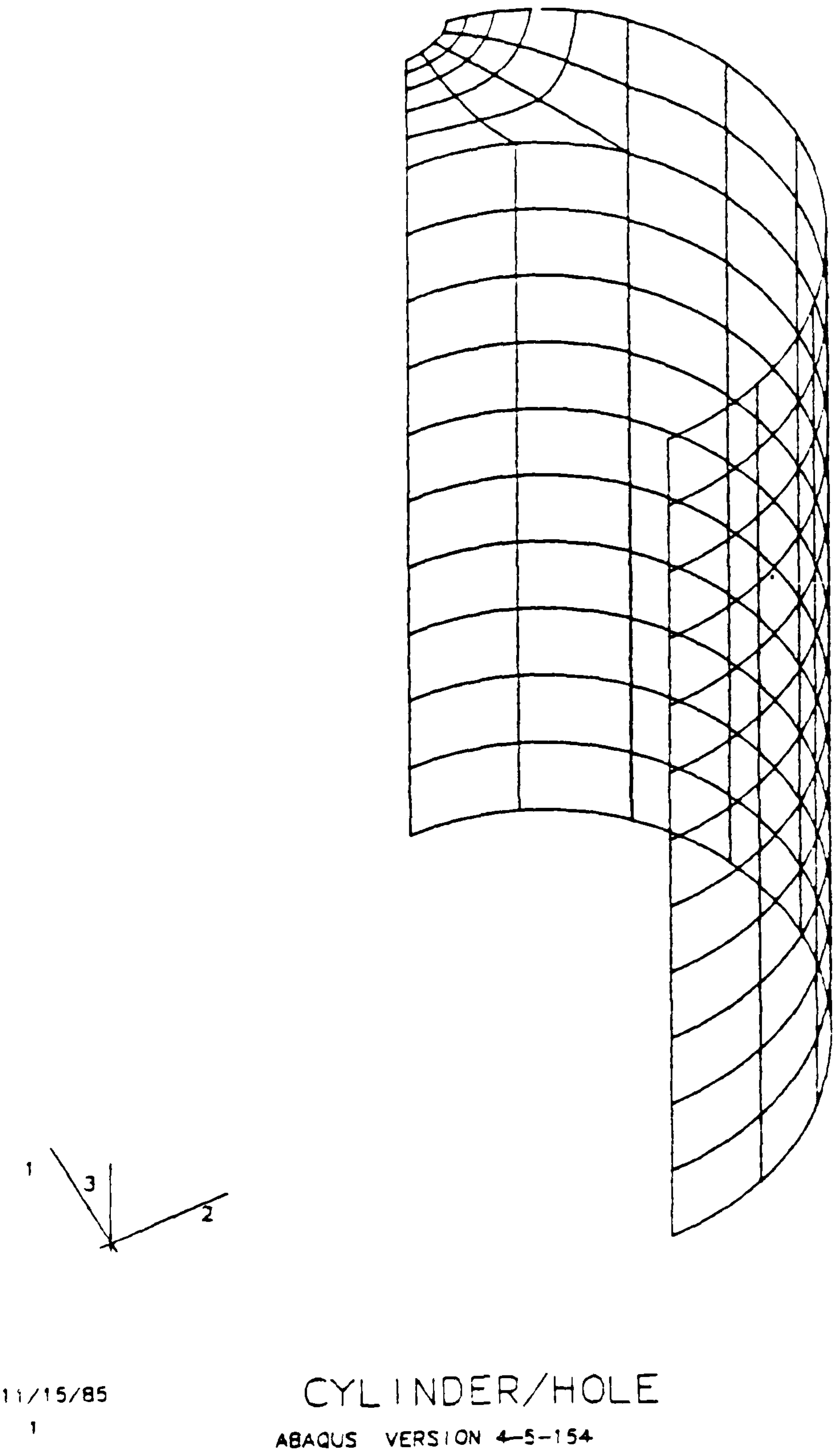


Figure 1. Undeformed finite element grid for the problem.

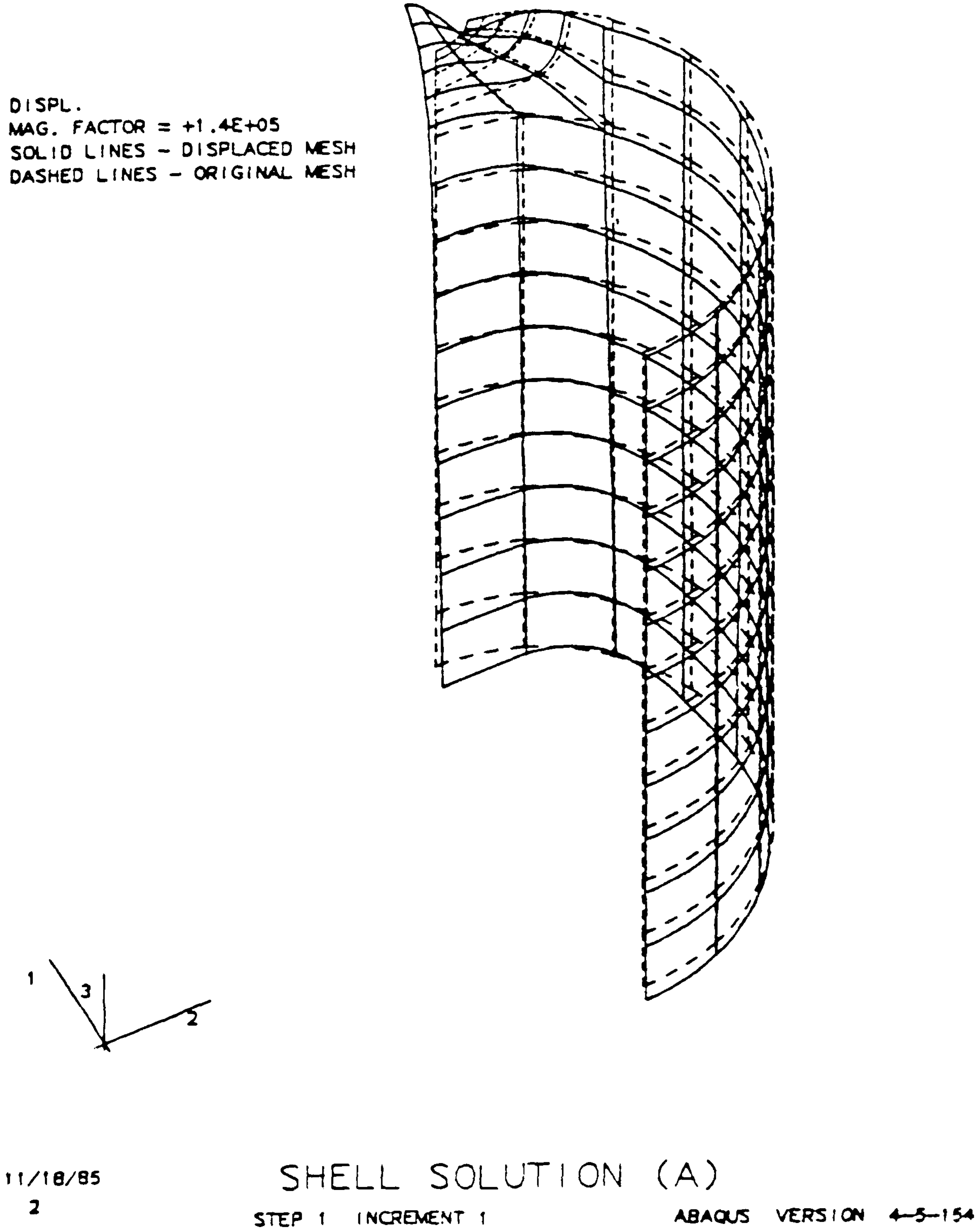


Figure 2. Deformed grid for solution A.

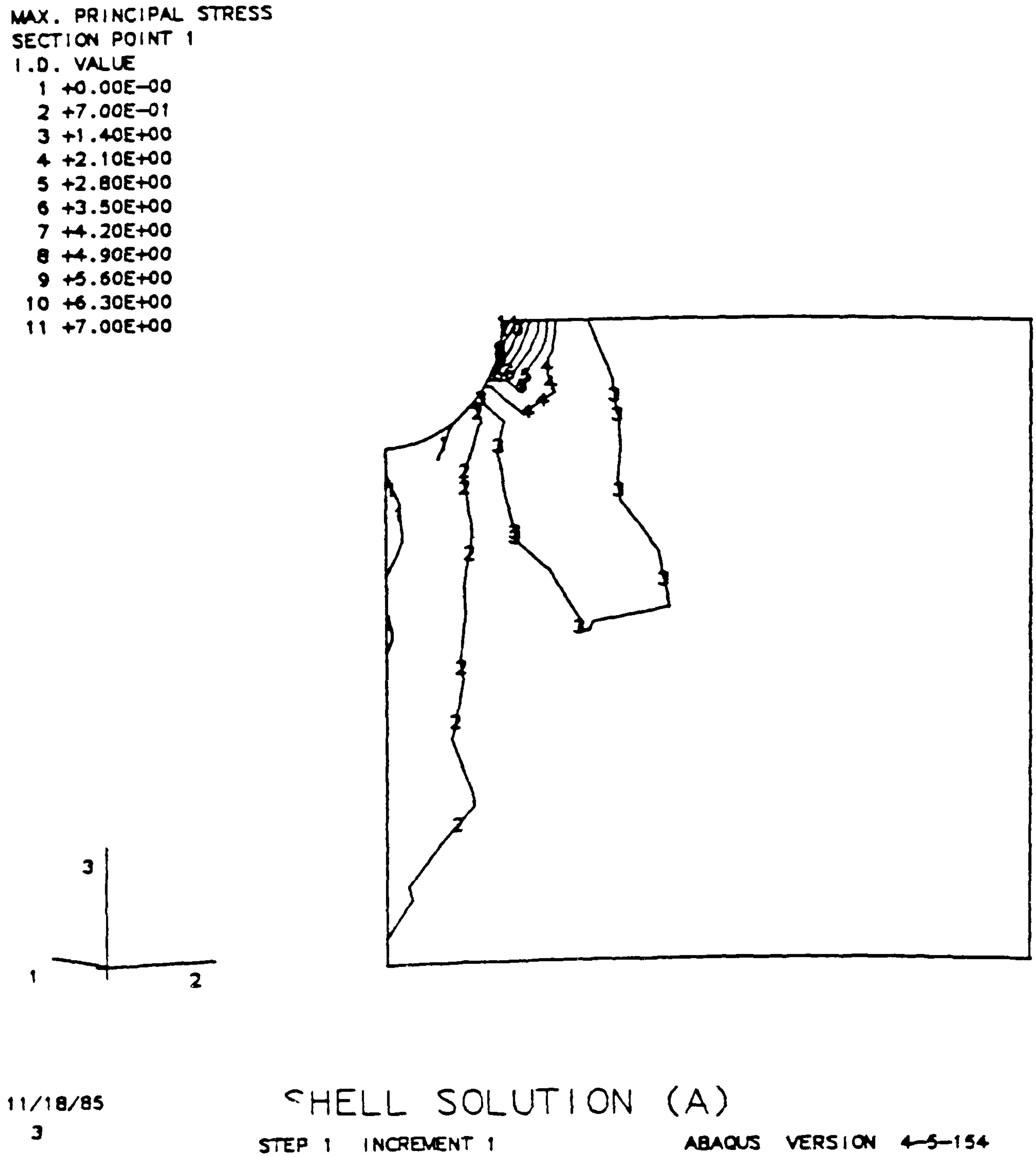


Figure 3. Near field maximum principal stress plot for the inner surface of solution A.

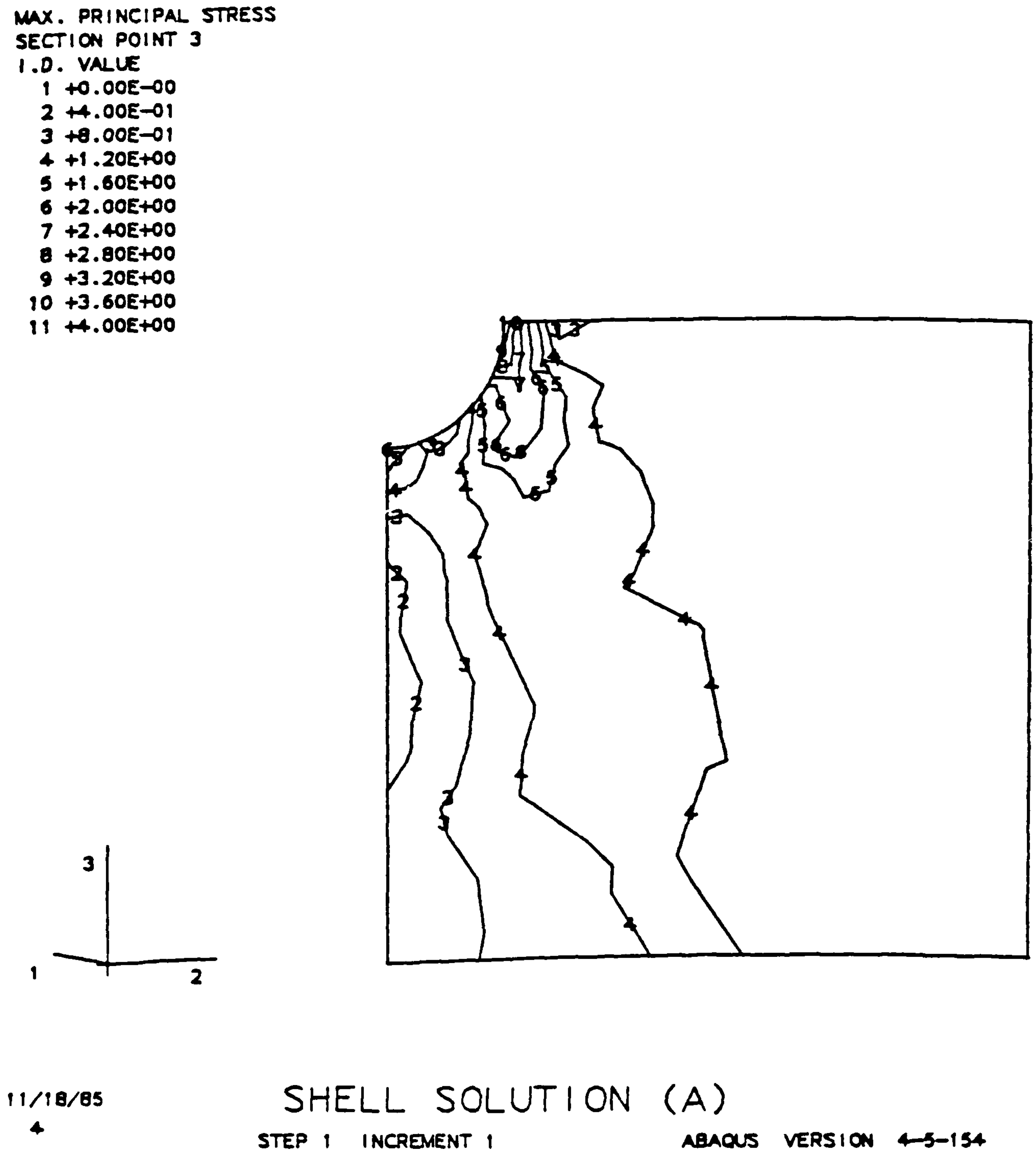


Figure 4. Near field maximum principal stress plot for the outer surface of solution A.

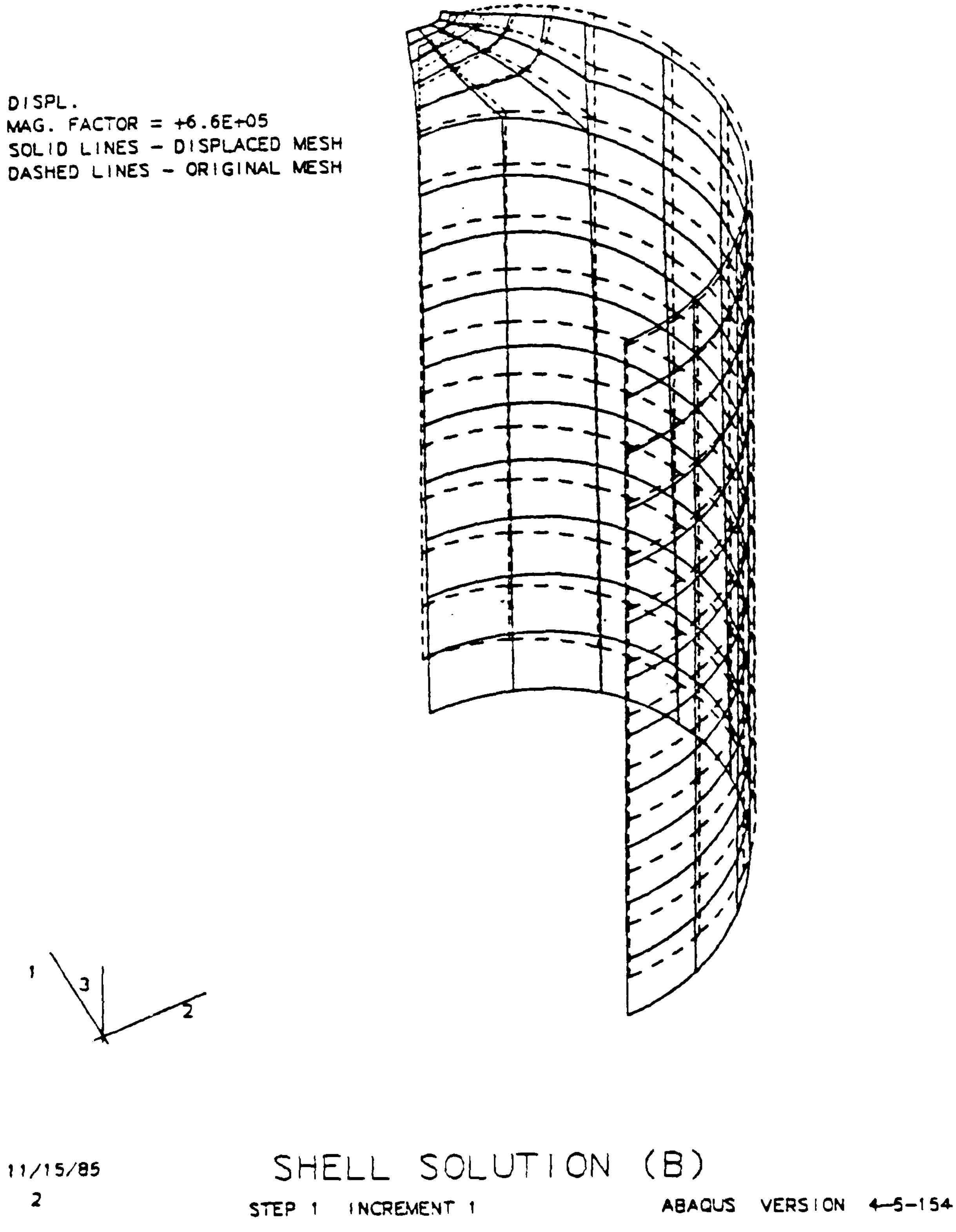


Figure 5. Deformed grid for solution B.

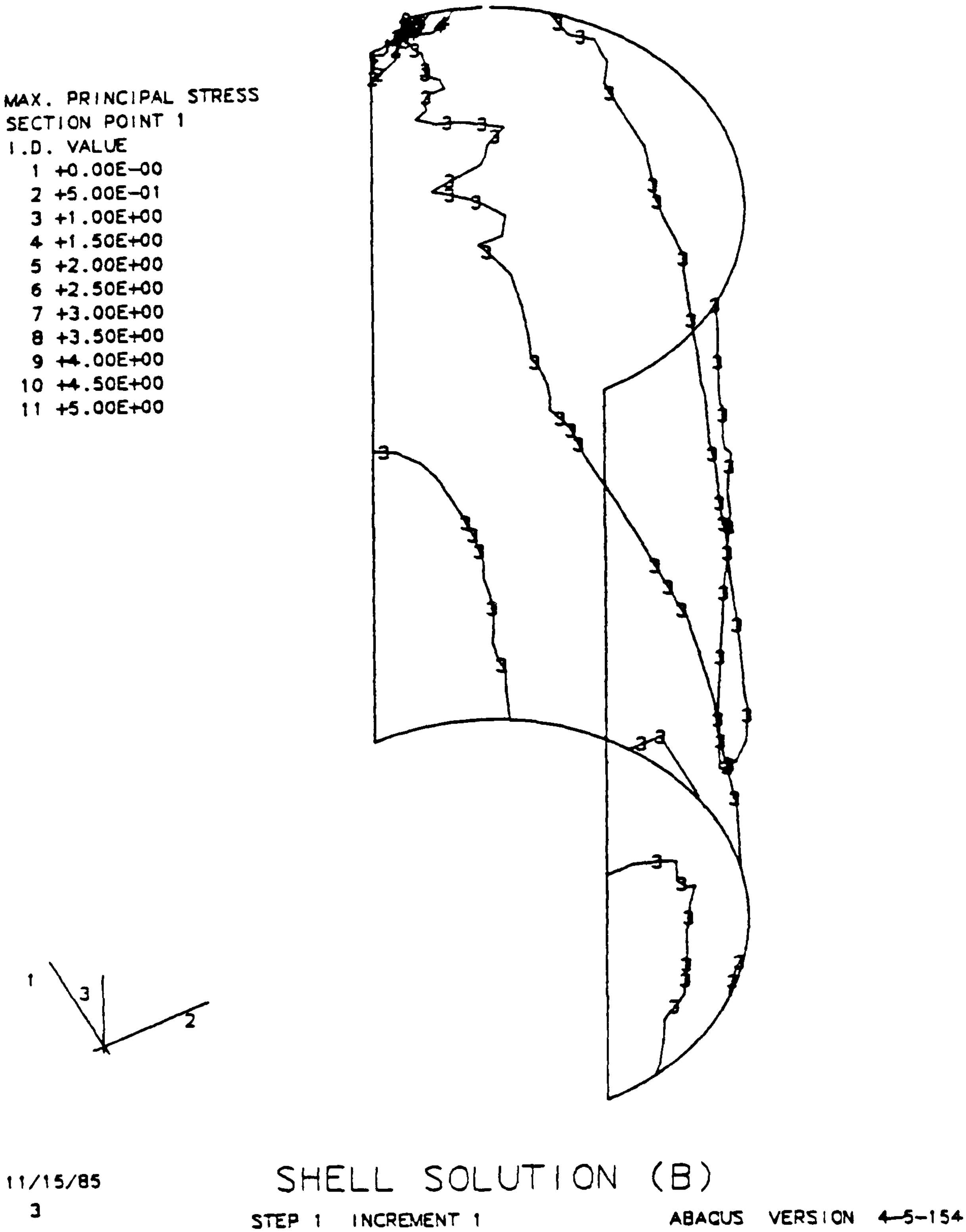


Figure 6. Far field maximum principal stress plot for the inner surface of solution B.

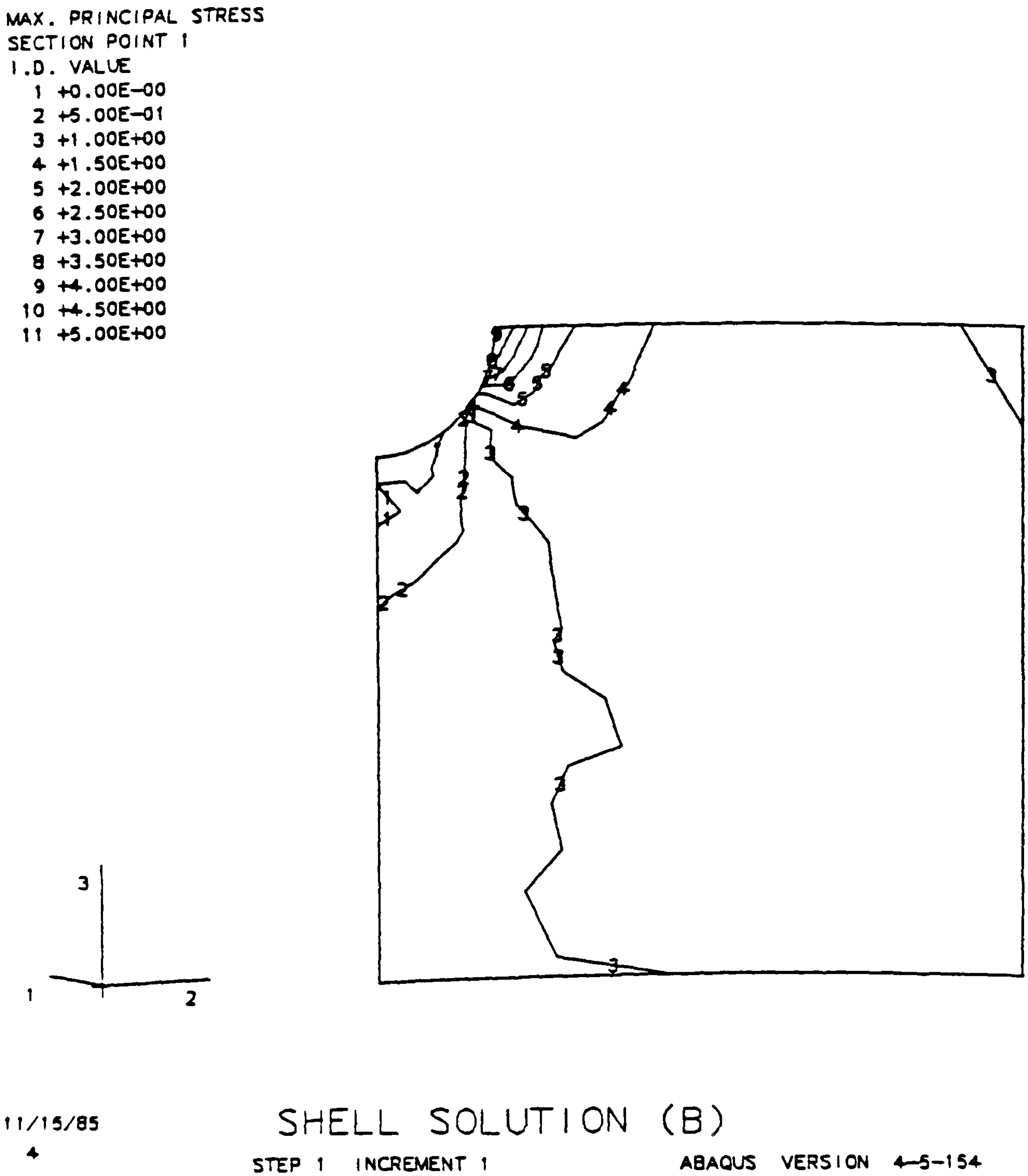


Figure 7. Near field maximum principal stress plot for the inner surface of solution B.

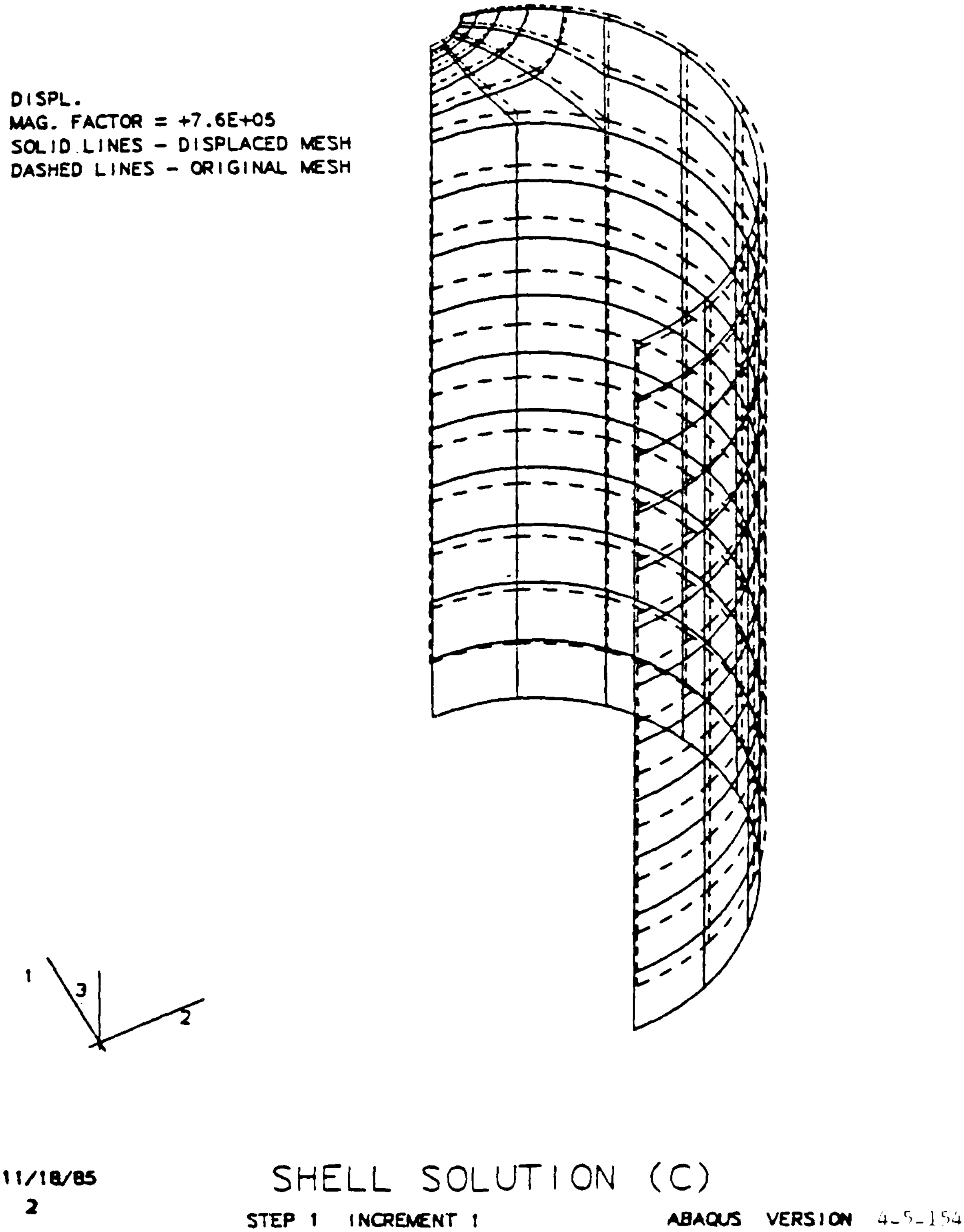


Figure 8. Deformed grid for solution C.

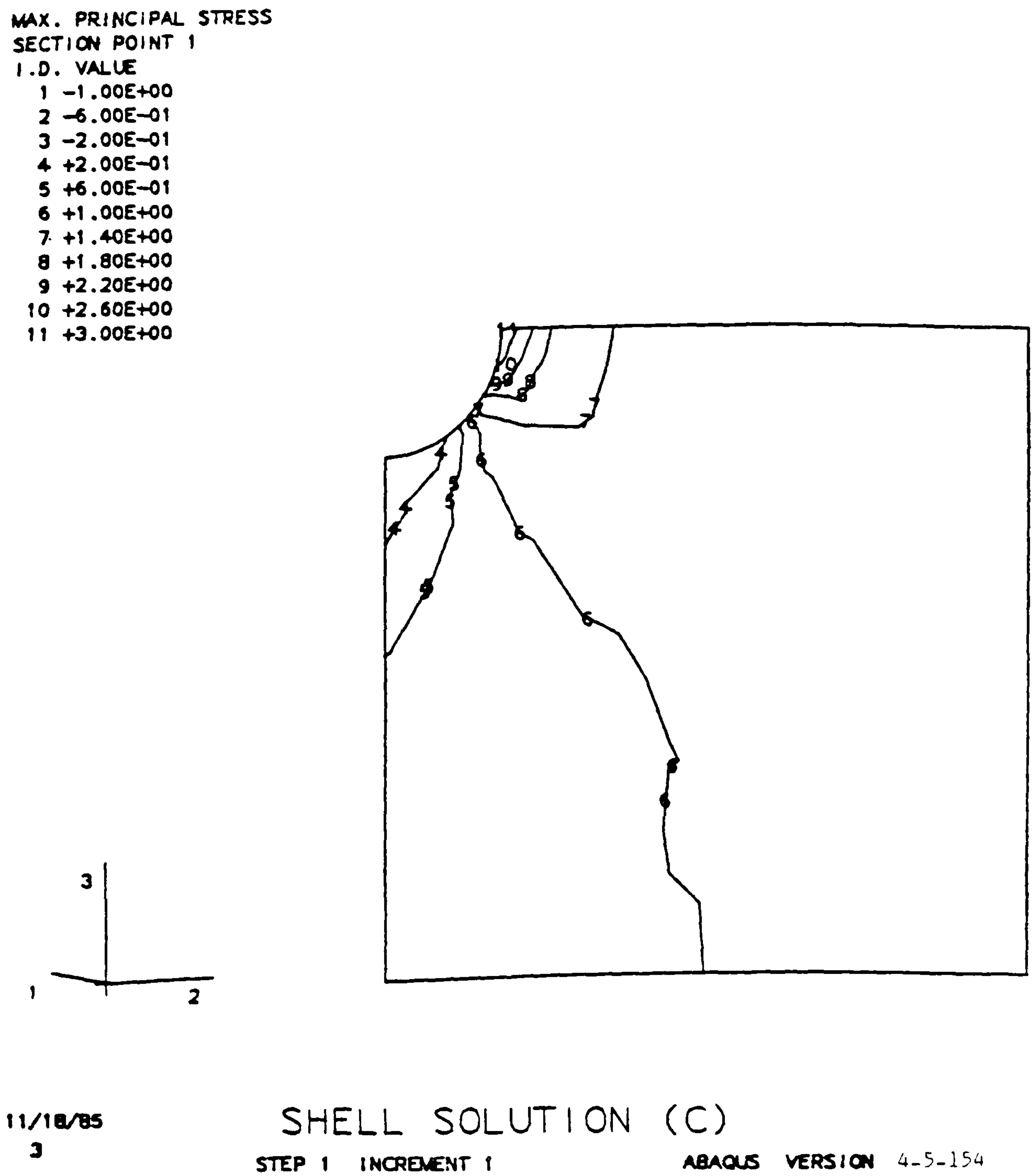


Figure 9. Near field maximum principal stress plot for the inner surface of solution C.

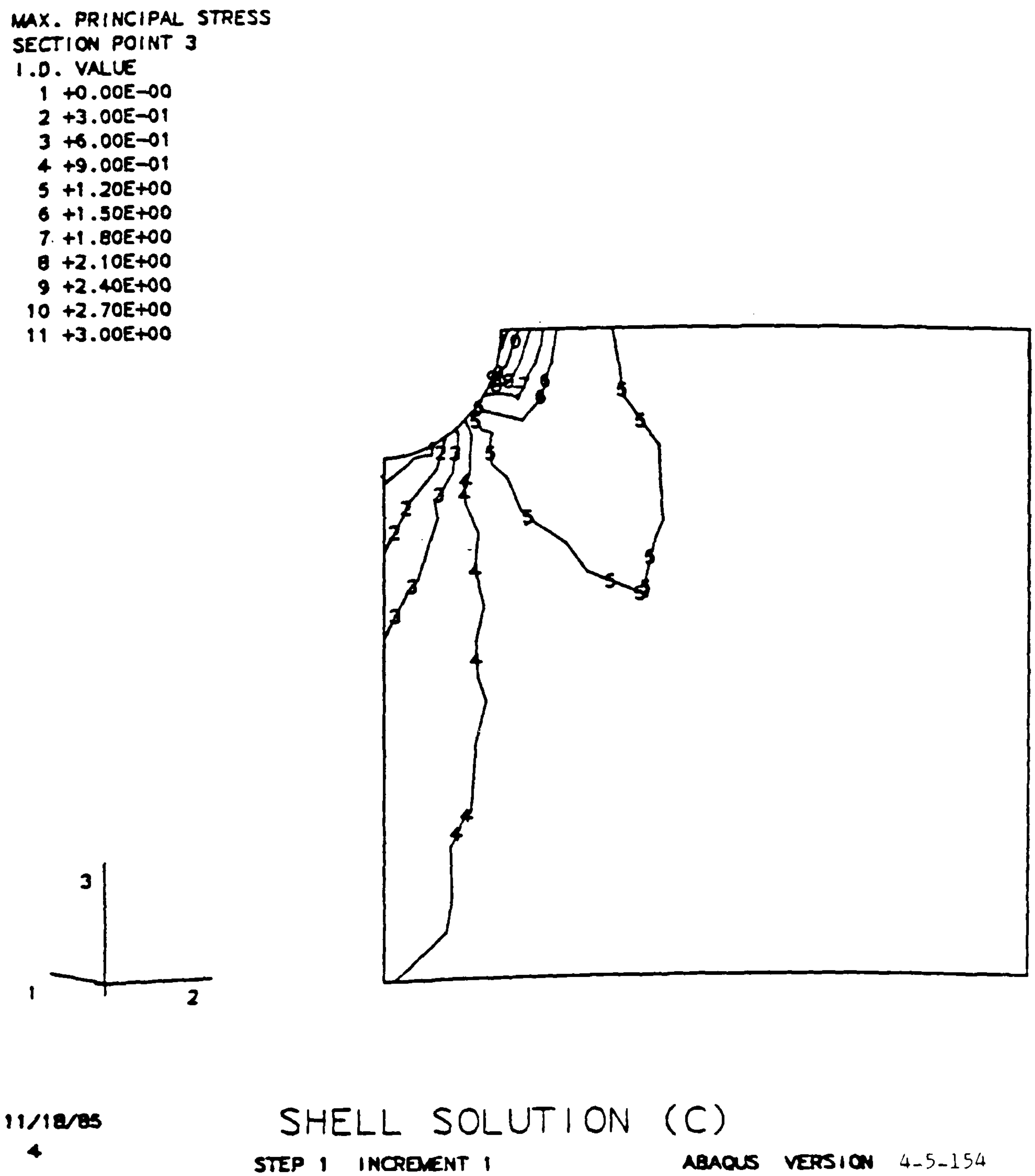


Figure 10. Near field maximum principal stress plot for the outer surface of solution C.

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